PESTS NOT KNOWN TO OCCUR IN THE UNITED STATES OR OF LIMITED DISTRIBUTION, NO. 52: MAIZE STREAK VIRUS

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Diseases — MAIZE STREAK. Streak disease of sugarcane, millet, and of many grasses. Wheat stunt.

Pathogen — Maize streak virus

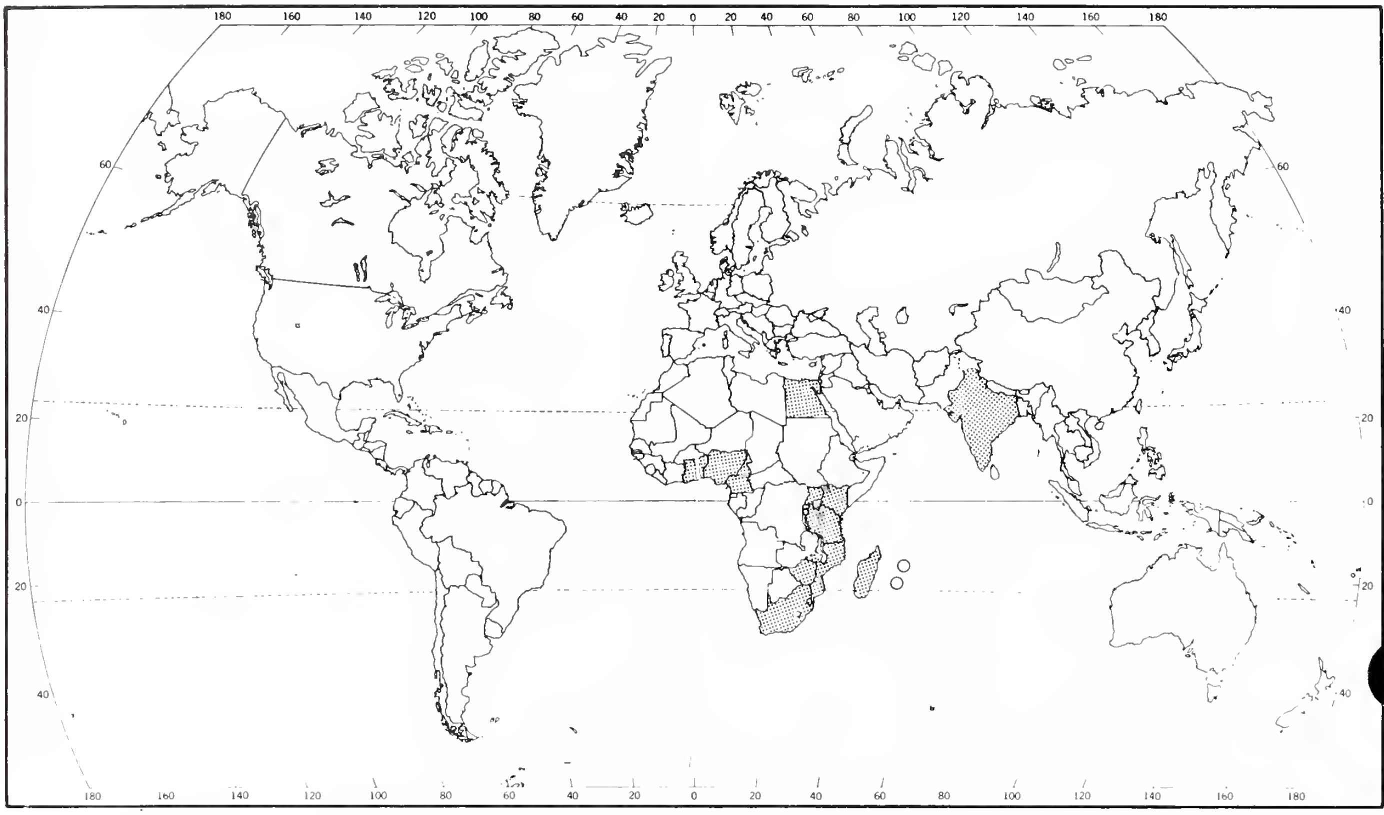
Group — Geminivirus. Cryptogram D/1:0.71/*:S/S:S/Au

Economic Importance — Maize streak virus (MSV) causes one of the important diseases of corn and other cereal crops in Africa. An epiphytotic in Nigeria occurred during 1973 on the second-season corn crop. Prevalence reached 90 percent or more in most corn-producing areas (Fajemisin, Cook, Okusanya 1976). MSV reached epidemic levels in the north-central area in 1983 (Keyser 1983).

Losses in Kenya were estimated at 33.3 percent for diseased plants in naturally infected corn plots. Yield loss trials there showed losses ranging from 61 percent in plants inoculated at the 1st leaf stage to 25 percent when infected at the 10th leaf stage. The level of loss corresponded more to the age of the plant at infection than to the number of plants infected (Guthrie 1978, Mauritius Sugar Industry Research Institute 1976). Generally, five to seven streaked leaves per corn plant at harvest resulted in 50 percent yield loss (C. Ricaud and S. Felix unpublished, cited by Rose 1978).

MSV is also important in other crops. Although streak disease no longer reduces yields in sugarcane in Natal, new cultivars must still be screened for resistance (Bock 1982). Previous yield loss in an old sugarcane cultivar was estimated at 12 percent, possibly as much as 30-50 percent (Storey 1925a). Streak ranged 30 to 100 percent in 10 of 15 sugarcane cultivars examined in Egypt (Ammar, Kira, Abul-Ata 1982). In wheat, MSV lowered some yields in India (Gorter 1947, Choudhary, Singh, Bhatnagar 1980).

General Distribution — Throughout Africa south of the Sahara and probably in Southeast Asia (Bock 1974). The following countries were obtained from Rose (1978) unless cited otherwise: Benin, Cameroon (IRAT 1977), Egypt, Ghana, India, Kenya, Madagascar (Bock 1974), Mauritius (Mauritius Sugar Industry Research Institute 1976), Mozambique, Nigeria, Reunion (IRAT 1977), South Africa (Storey 1925b), Swaziland (Martin 1982), Tanzania, Uganda, and Zimbabwe (Storey 1925b).



Maize streak virus distribution map prepared by Non-Regional Administrative Operations Office and Biological Assessment Support Staff, PPQ, APHIS, USDA

Hosts

Hosts include many genera in the grass family, Poaceae. Major crop hosts are Saccharum officinarum (sugarcane), Triticum aestivum (wheat), and Zea mays (corn). Tests of corn, the major host, revealed that most U.S. lines were susceptible (Damsteegt 1983). Some relatives of corn, the annual teosintes (Nault, Gordon, and others 1982) and some Tripsacum species (Damsteegt 1983), were also susceptible.

Most economic cereal grains were very susceptible to experimental inoculation. Some of these were Avena sativa (oats), Hordeum vulgare (barley), Oryza sativa (rice), Secale cereale (rye), and Sorghum bicolor (sorghum). Oats, rice, and wheat were more susceptible than barley and rye (Damsteegt 1980).

Many other grass species have shown streak symptoms (Gorter 1953, McClean 1947, Rose 1973a, Storey 1925a, and Storey and McClean 1930), but few assays were made. Over 130 native and adventive, annual and perennial grass species in the United States were tested for susceptibility. Almost one-half showed streaking. No hosts were symptomless (Damsteegt 1983).

Characters

MSV is identified by transmission with cicadellid vectors, by particle morphology, and by serology. Bock, Guthrie, Woods (1974) state that the viral morphology and short latent period in its vector are unique for leafhopperborne viruses. Acquisition and inoculation periods are short, and vectors remain viruliferous for life (Damsteegt 1980).

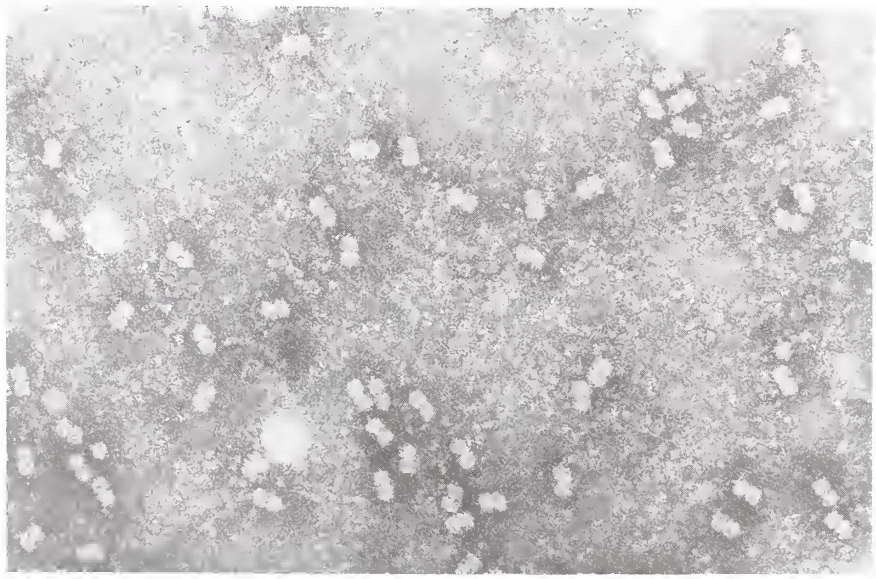
Transmission - Only by vectors in *Cicadulina* (Homoptera: Cicadellidae). *C. mbila* (Naude) and *C. bipunctella zeae* China are the most important and widespread. Others include *C. storeyi* China, *C. latens* Fennah, *C. parazeae* Ghauri (Bock 1974), and *C. triangula* Ruppel (Rossel and Thottappilly 1983). All nymphal instars and adults of both sexes of *Cicadulina* can acquire MSV and transmit it (Storey 1928). Some individuals in these species cannot transmit MSV.

The insect can acquire MSV in less than an hour of feeding on infected plants (Storey 1928), preferring the chlorotic areas (Heathcote 1975, cited by Rose 1978). Minimal latent period in *C. mbila* ranged 6-12 hours at 30° C before the leafhopper could transmit the virus (Storey 1928). The viruliferous leafhopper can then inoculate MSV by feeding on a healthy plant for at least 5 minutes, usually longer (Rose 1978). The vector retains the virus for a long time; one individual transmitted MSV for 5 months, and two others for at least 111 days (Storey 1925b).

The virus is not transmitted through the vector egg (Storey 1925b, 1928), through seed of corn (Fajemisin, Cook, Okusanya 1976, Storey 1925b) or wheat (Gorter 1947), or by mechanical means (Bock 1974, Fajemisin, Cook, Okusanya 1976, Seth, Raychaudhuri, Singh 1972, Storey 1925a). Transmission by dodder, *Cuscuta* sp., has not been reported (Bock 1974).

Morphology - Viral particles (Fig. 1) isometric, usually paired, individuals of pair 5-sided but single particles 6-sided (Bock 1974). Particle diameter 20 nm; paired, 30 nm X 20 nm (Bock, Guthrie, Woods 1974). Nucleic acid single-stranded DNA, predominantly circular, molecular weight 0.71 X 10^6 (Harrison, Barker, and others 1977).

(Fig. 1)



Maize streak viral particles (Courtesy V. D. Damsteegt).

Serology - Antiserum precipitin end point titers of 1:256 and 1:1,024 in agar gel and tube precipitin tests, respectively (Bock, Guthrie, Woods 1974). Thottappilly and Rossel (1980) successfully detected MSV in greenhouse and field-grown corn using ELISA (enzyme-linked immunosorbent assay).

Many strains of MSV were described after isolation from different grass species (Bock 1974, Bock, Guthrie, Woods 1974, Damsteegt 1980, Harrison, Barker, and others 1977, Rose 1978).

Characteristic Damage

Symptoms may vary with different crops.

Corn

Symptoms appeared on inoculated corn seedlings in 3-5 days but in 10-15 days on plants inoculated when 30 to 45 days old (Damsteegt 1980). Symptoms appear in young leaves formed after infection, rarely in the inoculated leaf; chlorotic areas are delimited before the leaf unfolds. Initially, almost circular, nearly colorless spots, diameter 0.5-2 mm, appear widely scattered on the lowest exposed parts of the youngest leaves (Fig. 2). Spotting becomes general over the base of the leaf and uniformly distributed over succeeding new leaves. Spots later elongate and coalesce into long, discontinuous chlorotic streaks running almost the length of the leaf (Fig. 3). The streaks are centered on secondary and tertiary leaf veins and the sides of primary veins, resulting in groups of five to

seven parallel streaks separated by irregular green lines (Figs. 4-5). Chlorotic tissue viewed by transmitted light generally appears as opaque yellow contrasting with the deep green of the leaf (McClean 1947, Storey 1925b).

(Fig. 2)

Early symptoms of maize streak on corn seedling (Courtesy V. D. Damsteegt).

Severity of symptoms is inversely related to plant age at infection. Field symptoms may thus range from plants with all except the two lowest leaves streaked, to plants with a few colorless spots near the base of the last leaf formed before the tassel appeared (Storey 1925b).

Besides streaks, plants may exhibit other symptoms when infected young. Stalk internodes and leaf length, especially in highly susceptible plants, may be shorter (A. C. Whitwell unpublished, cited by Rose 1978), and ears may contain none or fewer kernels with lower viability (Shurtleff 1980). Young plants may die (Soto and Buddenhagen 1978).

Barley, rye
Sorghum

Streaking was similar to maize streak (Damsteegt 1983).

Oats

Symptoms in <u>Avena sativa</u> and <u>A. fatua</u> (wild oats) appear as a diffuse chlorotic mosaic without streaking (Damsteegt 1980, Gorter 1953).

(Fig. 3)

Maize streak: Chlorotic spots beginning to coalesce on corn seedling (Courtesy V. D. Damsteegt).

Rice	Narrow discontinuous streaks appear in Japonica and Indica types. Plant height is reduced in seedling and mature plants (Damsteegt 1980, 1983).
Sugarcane	Streak is diagnostic. First chlorotic streaks appeared 2-3 weeks after inoculation. Secondary shoots are often fully streaked (Storey and McClean 1930). Broken, narrow, pale, straight streaks (Fig. 6) appear along the primary and secondary veins, evenly distributed over all leaves. The almost transparent streaks are 0.25-0.50 mm wide by 0.5-10 mm long. Fewer streaks appear on infected sugarcane than on infected corn. Streaks in adjacent rows do not fuse. Symptoms are distinct on the youngest, recently unfolded leaves. Young shoots arising from diseased seed cane at first show extreme

(Fig. 4)

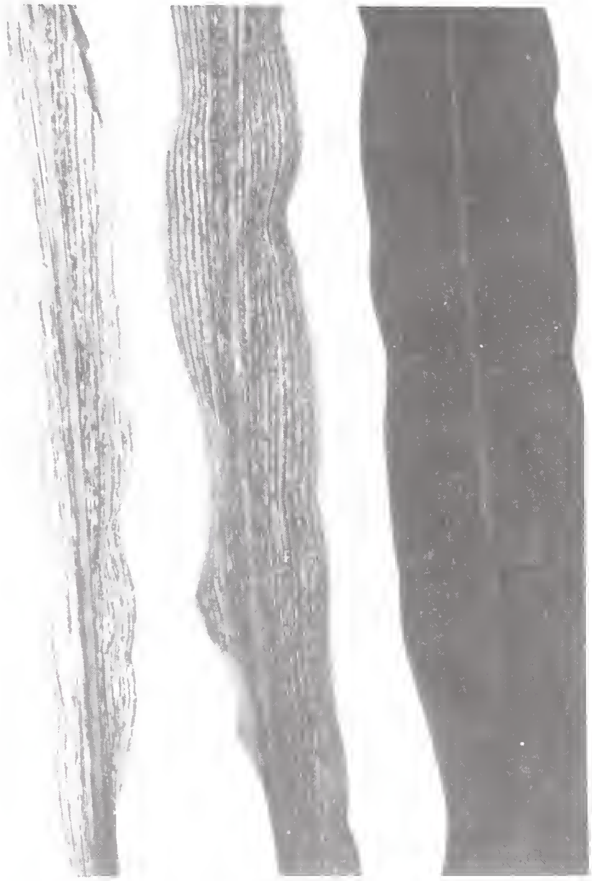
Maize streak fully developed on corn leaf (Courtesy V. D. Damsteegt).

widening of the streaks but later show the usual streak pattern. Viewed in transmitted light, chlorotic areas are almost transparent, not pale green or yellow (McClean 1947, Storey 1925a).

Other symptoms may not appear or may be caused by other conditions. These symptoms are stunted plants; lateral growth of young cane 1 m long or less with the short nodes crowding the leaves, giving a fanlike appearance; and narrow, crinkled leaves that do not hang in a smooth curve (Storey 1925a).

Infected sugarcane never recovers. Propagation of seed cane from infected plants results in diseased plants. Infected seed cane show no symptoms. Infected plants may initially appear symptomless (Storey 1925a).

(Fig. 5)



Maize streak: Left two, diseased; right, healthy leaf (Courtesy V. D. Damsteegt).

Wheat

The most characteristic symptom of wheat stunt is narrow yellowish green or chlorotic streaks along the leaf veins. As the disease develops, the first leaf to unfold is nearly always normal, but basal parts of the second or third leaf show a few streaks. These streaks increase in each succeeding leaf until the entire leaf is marked with parallel streaks. The width of the streaks is usually about 0.25 mm; length ranges from 0.25 to 3.18 mm. In severe infections, short streaks join to form longer lines parallel to the veins. Fully streaked leaves are much shorter than corresponding healthy ones. The tips often bend or curl (Gorter 1947).

Diseased plants (Fig. 7) appear small and bunchy because the stems remain short and tillering is stimulated. Stunting is an important field characteristic. Wheat heads bear few or no kernels. Bearded cultivars show some bent awns. Plants infected early are severely stunted or killed (Gorter 1947).

(Fig. 6)

Maize streak on sugarcane plants (Courtesy V. D. Damsteegt).

Detection Notes

Movement of the infected vegetative parts of the hosts of MSV with its vector Cicadulina spp. could introduce the virus into new areas. Visual inspection cannot always detect infected plant material. Infected sugarcane seed pieces are symptomless. Movement of the viruliferous vectors may present a potential threat to new areas.

Plants or plant parts capable of propagation are prohibited entry into the United States from most foreign localities where MSV occurs, except under departmental permit. Title 7 of the Code of Federal Regulations regulates corn and its relatives under Part 319.41; rice, 319.37; sugarcane, 319.15; and wheat, 319.59.

(Fig. 7)

Wheat stunt showing severe corkscrew, streaked leaves, stunted plants (Courtesy V. D. Damsteegt).

(Fig. 8)

Maize streak on corn showing affected younger leaves and unaffected older leaves (Courtesy V. D. Damsteegt).

1. Surveys for diseased plants --
Corn, Barley, Rye, Sorghum: Search for leaves with small white-yellow spots at the base of the youngest leaves, and long, discontinuous chlorotic streaks in fully formed leaves (Fig. 8). Symptoms are most distinct in the youngest leaves. Stalks and leaves may be shorter. Grain yield may be poor.

Oats: Look for leaves showing diffuse chlorotic mosaic.

Rice: Look for narrow, discontinuous streaks in the leaves and stunted plants.

Sugarcane: Search for plants with leaves that have broken, narrow, pale, straight streaks. Symptoms are clearly visible on the youngest leaves.

Wheat: Search for stunted, bunchy plants with streaked and curled leaves.

2. Search for the vectors in the funnel of leaves of young corn and other grass hosts. Adults of _C. mbila_ usually rest on the upper surface of young leaves forming the terminal cone of the plant, rarely on other parts (Storey 1925b). _Cicadulina_ species are 2-4 mm long and are marked yellow and black with two round black spots on the anterior margin of the crown of the head (Rose 1978). Consult Ruppel (1965) for the key to this group.

3. Submit for identification, suspect plant material in a manner to preserve its freshness as long as possible. Whole plants or leaves attached to stalks will last longer. Submit suspect _Cicadulina_ vectors mounted dry on triangular points.

Etiology

The initial source of MSV inoculum is believed to be in infected wild grasses or winter cereals. The vectors fly from drying grasses or ripening winter cereals to irrigated crops and later to corn. Rose (1978) explained that the disease increased in the field arithmetically or exponentially (compounded) as distinguished by Van der Plank (1963).

Spread in a linear arithmetic progression correlates with the number of viruliferous, long-distance _Cicadulina_ immigrants settling on the plants. These flights were estimated to be 1.8 km downwind with a possible 118 km covered in one flight. Because few of the immigrants are viruliferous and they stay a short time, little if any viral spread occurs (Rose 1974).

Exponential increase of the disease during early growth of the host plants may lead to epidemics. Then, the rate of invasion by the leafhopper, mostly short-distance flyers, is high, approaching one immigrant to every three plants. With this population density and with the high proportion of viruliferous leafhoppers before flight, the vectors spread MSV from plant to plant, and uninfected leafhoppers acquire the virus from infected plants and also spread it (Rose 1974, 1978).

Establishment of MSV in the United States depends on the presence of a vector. Although none of the known *Cicadulina* vectors occurs in the Western Hemisphere, some members of the genus do. They are *C. pastusae* Ruppel and De Long in Colombia and Ecuador, and *C. tortilla* Caldwell in Colombia, Peru (Rose 1978), and Puerto Rico. Results of the search for other vectors of MSV in South Africa (Storey 1925b, Storey and McClean 1930) and for vectors endemic to the United States (Graham 1979) were negative. One of the *Cicadulina* species in the Western Hemisphere, *C. pastusae* transmitted MSV only after it was injected with a concentrated viral preparation or after its gut wall was punctured (Graham, unpublished). Although no natural vectors have been found in the United States, studies of other plant viruses that have moved into new geographic areas have shown that new vector and virus combinations are possible (Damsteegt 1980).

Introduction and establishment of one of the *Cicadulina* vectors would most likely occur in such habitats as grassland areas under high rainfall or irrigation (Gorter 1953, Rose 1973b), rarely in areas with a long dry season. Damsteegt (1980) suggested that tropical, subtropical, and warm temperate areas in the Western Hemisphere could support populations of *Cicadulina*. The wide host range in native and adventive grasses could support the vector and the virus. Limited tillage practices could favor a grass reservoir for developing colonies of the vector. Crops grown with corn in the southern areas could serve as overwintering viral reservoirs and developmental hosts for *C. mbila* (Rose 1978). The adults can survive cold winters in parts of South Africa, especially in sheltered areas, where the mean lowest temperature is about 0° C (Van Rensburg 1982). In the laboratory, *C. mbila* survived -5° C for several hours. The virus itself survived up to 18 days in inoculated corn plants placed under 5° C days and 0° C nights (Damsteegt 1980). MSV could become serious if migratory domestic vectors evolved, acquired the virus in the southern regions, and carried it early in the growing season to the Corn (Graham 1979) or Wheat Belt.

Control

Development of resistant cultivars holds the most promise for control. Besides use of resistant cultivars, control of this disease involves eliminating the source of inoculum in wild grasses and crops. Fallow and clean cultivation destroys the source of infection in grasses or remnants of winter cereal crops, and crop rotation minimizes viral spread (Rose 1978, Gorter 1947, 1953). Managing the the vector is another factor in control.

Protecting the plants from the vector during the first 6 weeks after emergence minimizes losses. Bare ground appeared to be a more effective buffer to vector movement than buffer crops, including a resistant corn cultivar. A cleared zone 10 m wide between previously planted, infested corn and experimental plots reduced infection by 23 to 42 percent (Gorter 1953). Timing of planting to allow the seedlings to avoid main vector flights helps (Van Rensburg 1981).

With exponential increase of disease, eliminating the vector and diseased plants within the crop when streak incidence reaches the 5-percent threshhold generally may delay epidemics several weeks. Treating with pre-planting systemic or contact insecticides followed by roguing of infected plants and roguing again a week later was effective. Killing *Cicadulina* within a crop before roguing prevented the disturbed vectors from inoculating additional plants. Vectors feeding on infected plants nearby must also be eliminated (Rose 1974). Insecticide treatment may not be effective with arithmetic increase of maize streak incidence because new vector immigrants soon replace those killed (Rose 1978).

Literature Cited

Ammar, E. D.; Kira, M. T.; Abul-Ata, A. E. Natural occurrence of streak and mosaic diseases on sugar-cane cultivars in Upper Egypt, and transmission of sugar-cane streak by *Cicadulina bipunctella zeae* (China). Ann. Virol. (Inst. Pasteur) 133 E(2):183-185; 1982.

Bock, K. R. Maize streak virus. in CMI/AAB Descriptions of plant viruses no. 133. Commonwealth Mycological Institute and Association of Applied Biologists; 1974.

Bock, K. R. Geminivirus diseases. Plant Dis. 66(3):266-270; 1982.

Bock, K. R.; Guthrie, E. J.; Woods, R. D. Purification of maize streak virus and its relationship to viruses associated with streak diseases of sugarcane and *Panicum maximum*. Ann. Appl. Biol. 77(3):289-296; 1974.

Choudhary, G. G.; Singh, G.; Bhatnagar, G. C. Losses in yield components of wheat variety Lal Bahadur caused by streak virus disease. Indian Phytopathol. 33(4):604-606; 1980.

Damsteegt, V. D. Investigations of the vulnerability of U.S. maize to maize streak virus. Prot. Ecol. 2(3):231-238; 1980.

______. Maize streak virus: I. Host range and vulnerability of maize germ plasm. Plant Dis. 67(7):734-737; 1983.

Fajemisin, J. M.; Cook, G. E.; Okusanya, F.; Shoyinka, S. A. Maize streak epiphytotic in Nigeria. Plant Dis. Rep. 60(5):443-447; 1976.

Gorter, G. J. M. A. Wheat stunt -- a new cereal disease. Farming S. Afr. 22:29-32, 44; 1947.

______. Studies on the spread and control of the streak disease of maize. Union S. Afr. Dep. Agric. For. Sci. Bull. No. 341; 1953. p. 1-20.

Graham, C. L. Inability of certain vectors in North America to transmit maize streak virus. Environ. Entomol. 8(2):228-230; 1979.

Guthrie, E. J. Measurement of yield losses caused by maize streak disease. Plant Dis. Rep. 62(10):839-841; 1978.

Harrison, B. D.; Barker, H.; Bock, K. R.; Guthrie, E. J.; Meredith, G.; Atkinson, M. Plant viruses with circular single-stranded DNA. Nature 270(22/29):760-762; 1977.

IRAT Rapport annuel 1977. Paris: Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres; 1977. Taken from: Rev. Plant Pathol. 59(1):10; 1980.

Keyser, J. Maize streak epidemic in Nigeria. IITA Res. Briefs 4(4):1; 1983.

Martin, P. M. D. Estimate of crop losses due to common maize streak virus. Can. J. Plant Pathol. 4(3):308; 1982.

Mauritius Sugar Industry Research Institute. Annual report 1975. Port Louis, Mauritius: Mauritius Printing Cy. Ltd.; 1976. p. 40, 56-57.

McClean, A. P. D. Some forms of streak virus occurring in maize, sugar-cane, and wild grasses. Union S. Afr. Dep. Agric. For. Sci. Bull. 265. 1947.

Nault, L. R; Gordon, D. T.; Damsteegt, V. D.; Iltis, H. H. Response of annual and perennial teosintes (Zea) to six maize viruses. Plant Dis. 66(1):61-62; 1982.

Rose, D. J. W. Distances flown by Cicadulina spp. (Hem., Cicadellidae) in relation to distribution of maize streak disease in Rhodesia. Bull. Entomol. Res. 62(3):497-505; 1973a.

______. Field studies in Rhodesia on Cicadulina spp. (Hem., Cicadellidae), vectors of maize streak disease. Bull. Entomol. Res. 62(3):477-495; 1973b.

______. The epidemiology of maize streak disease in relation to population densities of Cicadulina spp. Ann. Appl. Biol. 76:199-207; 1974.

______. Epidemiology of maize streak disease. Annu. Rev. Entomol. 23:259-282; 1978.

Rossel, H. W.; Thottappilly, G. Maize chlorotic stunt in Africa: a manifestation of maize mottle virus? p. 158-160. In: Gordon, D. T.; Knoke, J. K.; Nault, L. R.; Ritter, R. M. eds. Proceedings International Maize Virus Disease Colloquium and Workshop, 2-6 August 1982. The Ohio State University, Ohio Agricultural Research and Development Center, Wooster; 1983.

Ruppel, R. F. A review of the genus Cicadulina. Publ. Mich. State Univ. Mus. Biol. Ser. 2:385-428; 1965.

Seth, M. L.; Raychaudhuri, S. P.; Singh, D. V. Bajra (pearl millet) streak: a leafhopper-borne cereal virus in India. Plant Dis. Rep. 56(5):424-28; 1972.

Shurtleff, M. C. ed. Compendium of corn diseases. 2d ed. St. Paul, MN: The American Phytopathological Society; 1980.

Soto, P. E.; Buddenhagen, I. Yield loss from a localized epidemic of maize streak virus in Nigeria. East African Agric. For. J. 44(2):175-177; 1978.

Storey, H. H. Streak disease of sugar-cane. Union of South Africa, Department of Agriculture, Science Bulletin 39; 1925a.

______. The transmission of streak disease of maize by the leafhopper Balclutha mbila Naude. Ann. Appl. Biol. 12:422-439; 1925b.

Storey, H. H. Transmission studies of maize streak disease. Ann. Appl. Biol. 15:1-25; 1928.

Storey, H. H.; McClean, A. P. D. The transmission of streak disease between maize, sugar cane, and wild grasses. Ann. Appl. Biol. 17:691-719; 1930.

Thottappilly, G.; Rossel, H. W. ELISA technique for detection of viruses of economically important food crops in the humid tropics of West Africa. IITA Research Briefs 1(1):1-2; 1980.

Van der Plank, J. E. Plant diseases: epidemics and control. NY: Academic Press; 1963.

Van Rensburg, G. D. J. Effect of plant age at the time of infection with maize streak virus on yield of maize. Phytophylactica 13(4):197-198; 1981.

______. Laboratory observations on the biology of Cicadulina mbila (Naude) (Homoptera: Cicadellidae), a vector of maize streak disease. 1. The effect of temperature. Phytophylactica 14(3):99-111; 1982.